Appendix F
Groundwater Technical Memorandum

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Pattle Delamore Partners Limited

TECHNICAL MEMORANDUM

INVESTIGATION	Groundwater Technical Report	**PROJECT**	Northern Corridor Improvements
CLIENT	Aurecon on behalf of NZTA	**PROJECT NO**	A02951602
CLIENT WORK ORDER NO/ PURCHASE ORDER		**PREPARED BY**	David Stafford
		REVIEWED BY	Aslan Perwick and Alan Pattle
		DATE	21 Sep. 2016

1. Introduction

Pattle Delamore Partners Ltd (PDP) has been engaged by Aurecon on behalf of New Zealand Transport Agency (NZTA) to predict the groundwater effects and dewatering inflows from the proposed Northern Corridor Improvements (NCI) construction through the closed Rosedale Landfill.

This report should be read in conjunction with the Primary Report -"Assessment of Effects – Corridor Encroachment on Rosedale Landfill (NCI-3PRE-2ENV-RPT-0026; 2016)". The aforementioned report is referred to throughout as the "Primary Report".

The purpose of this report is to detail the construction and development of the numerical model used to estimate groundwater effects and inflows as a result of the proposed NCI construction activities within the closed Rosedale Landfill site. Modelling results and interpretation is presented in the Primary Report.

Background

The New Zealand Transport Agency (NZ Transport Agency) is proposing options to secure planning protection for Northern Connection Improvements along Auckland's Northern Motorway. The Project area covers the area of SH18 between Albany Highway and Constellation Drive, and SH1 between the Upper Harbour Highway (UHH) interchange to just beyond the Oteha Valley Road Interchange.

2. Modelling Approach

A hydrogeological conceptual model of site is presented in the Primary Report. As is described in the Primary Report, the conceptual model is partitioned into regional groundwater (fully saturated zone) and a perched groundwater system within the unsaturated zone.

For the purposes of this study, the geological units outlined above have been grouped into five hydrogeological units according to their hydraulic properties, namely:

- Capping Fill: Interpreted to be present across the entire landfill at approximately 1 to 6 m thickness. Predominantly clayey SILT, won from local sources of ER (Opus, 2016)
- Refuse: Interpreted to behave hydraulically as a 'hard fill' of variable composition with a sediment matrix.
- TA: Sediment within stream valleys and gullies. Interpreted to be predominantly composed of clayey silts, with minor sandy silts.
- ER: Residual ECBF soil and completely weathered ECBF.
- EU - EW: Highly weathered, moderately weathered, slightly weathered and unweathered ECBF.

Conceptual Groundwater Flow

On a regional scale, the greatest volume of groundwater flow is within the EU - EW hydrogeological unit, with flow in a generally west to southwest direction towards the regional sinks of the inner Waitemata Harbour / Lucas Creek. However, overall flow is generally small in volume due to the low permeability of the unit as a whole. Volumes in the order of 10 m³ to 50 m³/day, per 100 m width of EU unit can be typically expected. Due in part to the low vertical permeability caused by the layering of sandstone and siltstone facies within the EU - EW, a component of vertical flow is common. Typically downward flow gradient in areas of higher topographic elevation i.e. near the top of catchment. Further down the catchment, upward flow gradients typically dominate as groundwater migrates towards discharge areas.

The EU - EW hydrological unit contains both unconfined and confined groundwater bodies. Typically the confined zones are located >10 m below saturation elevation due to the presence of siltstone layers which act as confining horizons. Groundwater flow within the EU unit is via both primary (between sediment grains) and secondary (fractures, faults, joints) permeability. Preferential groundwater flow paths can be associated with areas of more intense fracturing/faulting/jointing.

Typical within weathered ECBF geological sequences (EU - EW and ER) is the formation of 'perched' groundwater system(s). These form above the fully saturated regional groundwater system. Perched groundwater bodies typically form in the near-surface units i.e. <10 m below ground level. Occurrences of perched groundwater are typically localised, laterally discontinuous and discharge to local sinks i.e. surface drains, seeps, and streams. Perched water bodies may also be seasonal i.e. can dry out during summer

On a more local scale to Rosedale Landfill, regional groundwater discharges to the nearby surface water features; Oteha Stream and 'Stream A' (Rosedale Road Stream), as well as via westward through-flow primairly within the EU - EW unit to regional/downgradient sinks (Earthtech, 1995). Drawing SKT-2329 (of the primary report) displays the interpretted groundwater flow contours beneath and proximal to Rosedale Landfill, based on work completed within EarthTech (1995). The biannual, closed annual consent monitoring monitoring (T&T, 2016), and recent monitoring completed by PDP in July and August 2016, support the groundwater levels and contours presented in EarthTech (1995).

Recent monitoring (July and August 2016) of the gas migration monitoring wells, situated around the perimeter of the Rosedale Landfill, has identified an area of perched groundwater along the existing western flank at ~1.5 m below ground level (Gas Probe 2149). Other areas of perched groundwater may also exist within the vicinity and/or at deeper levels. It was considered that two zones of perched groundwater within the available unsaturated zone was a reasonable and conservative conceptualisation for this area of site.

3. Model Construction – Existing System

A 2D numerical model section was developed based on the conceptual understanding of site using the finite element model SEEP-W (GEO-SLOPE, 2012). SEEP-W accounts for both the saturated and unsaturated zone flow properties, and therefore both regional and perched groundwater systems were modelled concurrently.

The following hydrogeological system characteristics were represented within the model:

- 2D geological model – provided by Aurecon (Section A-A').
- Hydraulic properties – horizontal and vertical permeability functions, storage functions.
- Hydrological characteristics – recharge.
- Groundwater inflow to the model domain.
- Groundwater outflow from the model domain.
- Groundwater outflow to Oteha Stream
- Potential groundwater dewatering in to proposed excavation.

Geological Section A-A' at CH 2,300m (Aurecon, 2016; Drawing SKT-2345) was digitised within SEEP-W to create the distinct hydrogeological units outlined in Section 2 above. The calibrated existing system SEEP-W cross section is shown in Drawing SKT-2343.

The conceptualised perched groundwater layers were modelled by adding low permeability horizons within the ER unit. Vertical permeability of these horizons was altered until the saturated thickness of perched water sitting atop was 'calibrated' to what is conceptualised (~1 m to ~2 m saturated thickness). The finalised vertical permeability of the low permeability horizons was 1x 10^{-8} m/s.

Model Domain and Geometry

The model domains were chosen to ensure model boundaries would have limited effects on model predictions. Model geometry and mesh size are summarised in Table 2.

Table 2: Model Section Geometry

Parameter	Section A Cross-Section[1]	Description	Justification
Model Length	156m	East-West cross-section perpendicular to proposed cut excavation	Set at sufficient distance to minimise boundary effects on model predictions.
Lowest Elevation	-50m	Model base	
Highest Elevation	70m	Maximum topography	Base on Aurecon sections (Primary Report)
Element size	1 to 5m	Dimensions of elements in mesh	Appropriate scale of measurement for the modelling objectives and accuracy of input data.

Boundary Conditions

Constant head boundary conditions were applied to the east and west extents of the model to simulate inflow and outflow for the wider regional groundwater system. Head levels were based off the groundwater contour map shown in Drawing SKT-2329 of the Primary Report (adapted from (EarthTec, 1995)).

In order to simulate vertical groundwater head and flow gradients observed within the regional ER and EU - EW units, a series of constant head boundaries were created along the eastern and western edge of the model. Vertical head gradients were developed using existing data from nested piezometers presented in AEE Section 4 (EarthTec, 1995).

Surface recharge of 1.6×10^{-9} m/s, equating to approximately 50 mm/yr was applied to both the Landfill Cover and motorway embankment.

Model Calibration

Calibration of recharge and hydraulic conductivity for each model unit was undertaken at steady-state until the modelled head pressure distribution profile matched that the regional groundwater levels (EarthTec, 1995). This was a qualitative process, and involved altering hydraulic conductivity, recharge and the constant boundary conditions within an acceptable range based on available aquifer properties test data and literature values (Primary Report).

The final calibrated hydraulic property parameters are specified in Table 3. The values used are considered to be representative of the bulk aquifer properties for each unit. Water content functions and sample materials were determined using literature values and geological log descriptions.

Table 3: Calibrated Hydraulic Parameters in Synthetic Profile Model

Unit	Horizontal Hydraulic Conductivity (m/s)	Vertical to Horizontal Hydraulic Conductivity ratio	Saturated Water Content (% Vol.)	Residual Water Content (% Vol.)	SEEP/W Water Content Function
Landfill Cover	5×10^{-7}	1:1	30	1	Silty CLAY
Refuse	1×10^{-5}	1:0.5	40	5	Silty SAND
Clay Liner	5×10^{-9}	1:0.1	40	5	Silty CLAY
TA	1×10^{-6}	1:0.1	35	3	SILT
ER	1×10^{-7}	1:1	40	3	Silty CLAY
EU - EW	2×10^{-7}	1:0.1	10	1	Silty SAND

5. Parameter Sensitivity & Uncertainty Analysis

During the modelling and analysis phases, sensitivity and uncertainly testing was completed. Sensitivity analysis was performed qualitatively on each parameter and associated property zone to identify which parameters/properties induced the greatest influence on the quality of model calibration and thus where to focus modelling efforts. Key points from the sensitivity testing are summarised qualitatively below:

- Saturated Kh = low to moderately sensitive for saturated ER and EU - EW
- Saturated Kv = moderately sensitive for ER and EU - EW.
- Saturated Kh:Kv ratio = moderately sensitive
- Unsaturated Kh = highly sensitive for Refuse. Landfill Cover
- Unsaturated Kv =highly sensitive for Refuse and Landfill Cover
- Unsaturated Kh:Kv ratio =highly sensitive for Refuse and Landfill Cover
- Recharge = highly sensitive to recharge through the Landfill Cover.
- Storage and residual water content = highly sensitive within unsaturated zone.

Saturated permeability values associated with the ER and underlying EU -EW are generally well constrained by available literature values and previous on-site testing (EarthTec, 1995). As a result, calibration was largely focused on recharge, permeability and saturated water content of Landfill Cover and Refuse within the unsaturated zone. In order to prevent surface water ponding, Landfill Cover permeability was calibrated to $5x10^{-7}$ m/s, and recharge to 50mm/yr - supported by anecdotal evidence of its silty clay composition.

Relatively little is known about Refuse composition and spatial heterogeneity; permeability was set $1x10^{-5}$ m/s to prevent perched of groundwater within the modelled refuse. A single leachate monitoring bore situated within the landfill Refuse recorded approximately 5 m of landfill leachate head. However, no attempt was made to simulate leachate levels within the model given the high level of uncertainly regarding the variable composition and artificial leachate drainage network on site. Furthermore, it is assumed that all leachate present within the Refuse is contained/captured by the landfill clay liner and captured by the leachate drainage network.

6. Predictive Model

The steady-state calibrated model was altered to allow prediction of potential effects from the excavation associated with the proposed NCI works. This incorporated altering the model geometry to the proposed new landform, and applying seepage face boundary conditions to the proposed cut faces. The final predictive model is present in Drawing SKT-2344.

Recharge onto the pavement surface of the proposed works was also removed, given the impervious cover. Consequently, no perched groundwater forms within the predictive model as was occurring within the calibrated model.

7. Conclusion

- A 2D numerical model was developed and calibrated to simulate existing groundwater conditions, both regional and perched groundwater.
- The model was converted into a predictive mode to incorporate the changes associated with the proposed NCI works
- Perched groundwater does not form within the predictive model, primarily due to the removal of recharge where the new proposed paved surfaces are located.
- Regional groundwater is essentially unaffected within the predictive model, and hence groundwater levels and flow are essentially identical between the calibrated and predictive models.

8. References

- EarthTech Consulting Ltd (1995) Rosedale Landfill AEE: Section 4 Discharge of Contaminants to Land and Groundwater.
- GeoStudio Ltd (2012). SEEP/W version 8.15.5.11777
- Tonkin & Taylor (2016) Closed Landfill Consent Monitoring Report; Rosedale Closed Landfill – May 2016. Report prepared for Auckland Council – Closed Landfill & Contaminated Land Response Team.

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